The Beet Leafhopper

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The beet leafhopper is the only known carrier of curly top, a destructive virus disease of sugar beets, beets, beans, tomatoes, spinach, melons, other crops, ornamental flowering plants and many weeds. The insect favors arid and semiarid localities of the western United States, northern Mexico, and southwestern Canada. Its breeding grounds are abandoned and overgrazed lands on which weed hosts occur. Such areas are also reservoirs for the virus.

Curly top has been given many common names—on sugar beets it has been called California beet blight, western blight, blight, curly leaf, and curly top; on tomatoes, tomato blight, yellow blight, summer blight, western blight, western yellow tomato blight, tomato yellows, and tomato curly top; on beans, bean blight.

How serious it can be is shown in records for southern Idaho, where growers of sugar beets in 1924 abandoned 11,442 out of 22,418 acres they planted. In 1934 they abandoned 18,635 out of 21,389 planted acres. The average yields of the harvested fields were 5.51 and 4.88 tons an acre for 1924 and 1934—far below the 16-ton average in years of little leafhopper exposure. Factories were dismantled and moved to other places, only to be dismantled and moved again when it was found that they had been relocated in areas infested by the beet leafhopper.

A leafhopper can pick up the virus from a diseased plant and transfer it to a healthy plant in 4 hours. Once a leafhopper has become infected with the virus of curly top, it remains infective, but it cannot transmit the virus through the eggs to its progeny.

Serious losses to cantaloups and muskmelons have been reported in Arizona, California, Idaho, and Utah. In 1945, N. J. Giddings, a specialist on curly-top virus, found that flax from the San Joaquin Valley, Calif., was infected with curly top. Later tests indicated the possibility of serious injury to flax during seasons of high infestations.

THE BEET LEAFHOPPER, commonly called the whitefly in the West, is slightly more than one-eighth inch long. It is gray to greenish yellow. It is a sun-loving, dry-climate insect and often breeds on many species of introduced weeds established on nonagricultural and deteriorated range lands. It feeds by sucking juices from its host plants. Rarely does it become numerous enough to cause great direct damage by its feeding. It is important then only because it carries curly top.

The virus of curly top survives the winter in both the beet leafhopper and its winter host plants. The leafhopper transmits it during feeding. It is carried from the winter hosts to other weed hosts and cultivated susceptible crops, principally during the spring movement. Some of the crops in their seedling stage are very susceptible to the disease. Infected plants often die. The percentage of the spring-generation leafhoppers carrying the virus has varied from year to year, with a low of 4 percent and a high of 80 percent.

Varieties of sugar beets that are resistant to curly top have been developed. We have no commercial varieties of tomatoes that are resistant. Serious losses occur during years of leafhopper outbreaks in parts of California, Colorado, Oregon, Utah, and Washington. In southern Idaho and some other areas, tomatoes are not grown for commercial use, because the crop is practically a complete loss in years of drastic exposure to curly top.

Most varieties of snap beans are susceptible. Southern Idaho produces approximately 80 percent of the national requirement of garden seed beans. The area is free from bacterial blight and

other seed-borne bean diseases. During years when large spring movements of hoppers coincide with the "crookneck," or seedling, stage, field after field of the most susceptible varieties of beans in southern Idaho have been so seriously damaged by curly top that it has been necessary to plow them under. Losses to less susceptible varieties have also been high. In the past, serious losses occurred in most of the varieties of the field, or dry, beans. The Idaho Agricultural Experiment Station has developed resistant varieties of Great Northern and pinto beans.

THE EARLIEST VISIBLE SYMPTOMS of curly top in beets are the clearing of the tiny veinlets and the inward rolling of the lower and outer margins of the youngest leaves. As the disease gets more severe, the curling and distortion of the leaves increase, vein swelling occurs, and numerous papillae, or wartlike bumps, appear on the under sides of the leaves. A general stunting often ends in the death of the plant in the most severe cases. The diseased leaves are dark, dull-green, thick, crisp, and brittle. The roots show marked symptoms. The disease causes the death of the lateral rootlets and the beet then sends out a large number of new lateral rootlets, which look hairy or woolly. A cross section of a diseased root often shows dark concentric rings alternating with light circular areas. A longitudinal section shows the dark discoloration extending lengthwise throughout the beet.

In beans the first symptoms are the most pronounced on the trifoliate leaves, which become slightly puckered, curl downward, turn yellow, and die. They and the primary leaves are thicker than normal and brittle and break off readily. The infected young plants soon die. Plants infected later in the season may drop their blossoms, become chlorotic, and die. Affected plants are decidedly dwarfed and have short internodes, which give them a bunchy appearance. Plants infected late in the season do not always develop typical symptoms of the disease and generally grow to maturity.

In tomatoes the first reliable symptom is a general drooping, but not wilting, accompanied by yellowing of the young leaves and purpling of the veins. The plant is abnormal—often silvery—in color. The leaves thicken and become leathery and brittle. The entire plant turns yellow and usually dies. In seriously diseased plants the blossoms may drop and no more fruit is set. Fruits that are already formed turn yellowish red, ripen prematurely, and are stunted and of poor quality.

In squash the symptoms are somewhat similar to those in the other susceptible commercial crops. If the young seedling is infected by virus-carrying leafhoppers as soon as it emerges above the soil, it may die before its true leaves appear. In the older infected plants, new growth is stunted, internodes are shortened, and the leaves may roll upward at the margins. An upward bending of the tip of the runner is characteristic. Blossoms may drop and not set fruit, and the fruits already formed are stunted. There are no distinctive color differences by which a diseased plant may be identified. Wilting is not characteristic of curly-top infection in squash plants.

Infected cantaloups show no reliable symptoms. Infected seedlings become severely stunted and usually die. In the older infected plants, new growth is stunted, internodes are shortened toward the end of the runners, and the leaves may become puckered with the margins turned down. The flowers become dwarfed and often become dry before the petals expand. Yellowing occurs in severe cases.

Spinach affected by curly top undergoes stunting, shows crinkling and curling of the leaves, and acquires a more leathery texture and, in severe cases, yellowing of the leaves.

Considerable variations may occur in the symptoms of the infected plants, depending on the strains of the virus. The length of the incubation period and the severity of the disease that de-

velops depend on the age and condition of the plant, its resistance, virulence of the virus, temperature, relative humidity, and light intensity. High temperature, low relative humidity, and high light intensity all increase the severity of the disease and the rate of development. Irrigation does not check the disease. Serious epidemics of curly top are dependent on several contributing factors—magnitude and time of the movement of spring-generation leafhoppers, percentage of leafhoppers carrying the virus of curly top, size and condition of susceptible plants at the time of infection, and weather conditions.

The first variety of beets resistant to curly top, U. S. 1, was developed by the Bureau of Plant Industry, Soils, and Agricultural Engineering and was released to growers in 1934. Since then, other resistant varieties have been released. Each is an improvement in resistance and adaptation. The development of varieties of sugar beets resistant to curly top has greatly lessened the losses to the crop. Eubanks Carsner and F. V. Owen have told the story in *Science in Farming,* the 1943–1947 Yearbook of Agriculture, of the research that made this possible.

The development of resistant varieties of sugar beets has made it profitable to grow beets again in areas of the western part of the United States that are affected by the beet leafhopper. Even the resistant varieties are susceptible to curly top in the early stages of growth, however, although they are far more resistant to injury than the nonresistant varieties previously grown, such as Old Type. Although the threat of failure to the beet crop has been greatly lessened, curly top has not vanished, as serious losses from curly top have occurred in California, Idaho, Nevada, and Utah in recent years when large spring movements of beet leafhoppers have coincided with the susceptible seedling stage of the plant. Although the losses have been local in extent, they have dealt hard blows to growers in affected areas. There is also the possibility that new and possibly more virulent strains of the virus of curly top will have to be dealt with.

Since the beet leafhopper survives only in a dry climate, it has probably reached the limits of its economic distribution in North America. The general climatic condition, rather than its host plants, is the limiting factor in restricting further geographical distribution of this insect, as its summer, winter, and spring breeding host plants are found growing abundantly outside of its economic range.

In only two instances has the insect been reported in the Eastern States. D. M. DeLong found it reproducing on purslane sesuvium (*Sesuvium portucastrum*) at Miami, Fla., in 1921. In 1936 he and K. J. Kadow collected it from horseradish at Collinsville, Ill.

An occasional outbreak of the insect and the curly top disease may be expected in areas removed from its normal range. Such outbreaks have occurred in the past in the Big Horn Basin, Wyo., and near Billings, Mont. Those outbreaks evidently followed long-distance migrations of the leafhopper into the areas, followed by favorable weather conditions for the insect for a few years. Because the disease depends on the vector for its spread, it is limited to the region infested by the beet leafhopper.

THE BEET LEAFHOPPER passes the winter in the adult stage, chiefly in uncultivated and overgrazed areas where mustards or other suitable host plants grow. The insects are active and feed during the winter whenever the temperature permits. The female develops its eggs in late winter. Egg-laying usually begins about the time the host plants begin spring growth. The eggs are laid inside the tissues of the leaves and stems of plants. A single overwintered female has been known to deposit 675 eggs. The average is between 300 and 400. The eggs hatch in 5 to 40 days, depending on the temperature. The young leafhoppers, the nymphs, emerge from the eggs and

immediately begin to feed by inserting their beaks into the plant tissue and sucking the juices. The tiny nymphs are white, but in a few hours they darken considerably. As they grow they shed their skins five times, becoming larger after each molt. The older nymphs are usually spotted with red and brown. After the fifth molt, they become adults and have wings.

The time required for nymphal development from the time the insect hatches until it is adult is 3 to 6 weeks. Development from egg to adult takes 1 to 2 months. The generations overlap considerably. All stages may be found in the same breeding area at the same time in summer. The beet leafhopper breeds continuously during the warm months, and nymphs may be found at any time during the growing season. In the Central Columbia River area of Oregon and Washington, on the Snake River Plains of southern Idaho, and in northern Utah, three generations are produced each season. In the warmer regions in Arizona and California, five or more generations may develop.

The first, or spring, generation is produced on spring weed hosts, chiefly mustards, that are rather short-lived and mature and dry about the time the spring-generation leafhopper reaches the adult, or winged, stage. When weather conditions are favorable for flight, the leafhoppers move to their summer hosts, the progress of which coincides with the maturation of the insect. They travel with the wind and infest practically all host plants in their path. Most of the favorable summer host plants are weeds.

The infestation of crop plants is incidental to the general movements of the leafhopper, as they do not actively seek these out but infest any favorable host in their path. The leafhoppers moving into the cultivated areas alight first in the fields nearest the spring breeding grounds and gradually move farther into the cultivated lands. Consequently beets, beans, tomatoes, and other susceptible crops nearest the breeding grounds are more heavily infested than those farther away and are, therefore, more seriously affected with curly top. Of the cultivated plants, beets are the only important breeding host. Spinach and Swiss chard are less favorable. During the spring migration, the leafhopper will feed on beans, cantaloups, squash, tomatoes, and other crops but will not reproduce on them. It is during such feeding that the plants are infected with the virus of curly top.

The wild host plants of the beet leafhopper usually occur in large patches scattered over definite areas. Such areas, where large numbers of favorable host plants combine with favorable climatic conditions, are very productive of leafhoppers. It is difficult to trace the flights of such tiny insects, and much remains unknown about their movements. Yet it is known in a general way that leafhoppers from any one breeding ground infest the same cultivated areas year after year.

All the breeding grounds, except the ones along the Rio Grande in New Mexico and Texas, are west of the Continental Divide. All are in areas with a mean annual rainfall of not more than 12 inches. In all except the Arizona and Rio Grande areas, the summers are dry, and the heaviest rainfall is in winter or spring. In southern Arizona and New Mexico and in southwestern Texas, there is an appreciable winter rainfall, with another rainy period late in the summer. The quantity and distribution of rainfall in all breeding grounds are such that practically all agriculture depends upon irrigation. The summers are hot and dry in all breeding areas, but the winter climate varies greatly. In the central Columbia River breeding areas of Oregon and Washington and on the lower Snake River Plains of Idaho and eastern Oregon and in western Colorado, northern Nevada, and northern Utah, heavy snows and subzero temperatures are not uncommon. In the southern breeding areas, the moisture falls as rain, and the winters are short and cool.

The six most important breeding areas of the beet leafhopper are: Area 1, San Joaquin Valley in California; area 2, lower Colorado River drainage area; area 3, the Rio Grande area of southern New Mexico and western Texas; area 4, scattered breeding areas of western Colorado, Nevada, and Utah; area 5, the lower Snake River Plains of Idaho and eastern Oregon; and area 6, the central Columbia River of Oregon and Washington.

The important breeding areas that affect agriculture in the Great Valley of California lie along the foothills on the west side of the San Joaquin Valley. The largest overwintering and spring breeding grounds are in the eastern foothills of the Coastal Range, while the summer breeding grounds are in the Valley.

The lower Colorado River drainage breeding areas lie in southwestern Arizona, southeastern California, southern Nevada, and southern Utah. These are the most extensive spring breeding areas in the United States, and leafhoppers moving from them affect agriculture in Arizona, Utah, and western Colorado.

The breeding areas of western Colorado, northern Nevada, and northern Utah are small, localized, and scattered, and leafhoppers from them affect adjacent agricultural crops. The most important is within the Great Salt Lake Basin.

In Idaho and eastern Oregon, the breeding grounds are on the Snake River Plains at elevations below approximately 4,500 feet. Some summer reproduction occurs above this elevation, but these areas are generally repopulated each spring. The spring movements generally progress eastward across the Snake River Plains.

The breeding areas of Oregon and Washington lie in the dry sagebrush plains of the Columbia Basin from the Grand Coulee to central Oregon. Leafhoppers from those places infest sugar beets and other susceptible crops in the Yakima and Walla Walla Valleys and other smaller irrigated areas. In certain seasons they may be blown down the Columbia Gorge into the Willamette Valley.

Because the leafhopper does not hibernate during the winter but must feed when temperature permits activity, it requires a sequence of host plants. The principal plants on which it overwinters and produces one or more spring generations in the major breeding areas are mustards. The principal spring host plants in the various breeding areas are: Area 1, peppergrass (*Lepidium nitidum* and *L. latipes*), desert plantains (*Plantago insularis, P. fastigiata,* and *P. erecta*), and filaree (*Erodium cicutarium*); area 2, peppergrass (*Lepidium lasiocarpum*), patata (*Monolepis nuttalliana*), and desert plantain (*Plantago fastigiata*); area 3, perennial peppergrass (*Lepidium alyssoides*); area 4, filaree, blistercress (*Erysimum repandum*), and African mustard (*Malcolmia africana*); area 5, flixweed (*Descurainia sophia*), green tansymustard (*D. pinnata* ssp. *filipes*), perfoliate peppergrass (*Lepidium perfoliatum*), and tumblemustard (*Sisymbrium altissimum*); area 6, filaree, tumblemustard, flixweed, and green tansymustard.

Russian-thistle (*Salsola kali* var. *tenuifolia*) is the most important summer weed host of the leafhopper in the western United States. Other important summer host plants in various breeding areas are: Area 1, bractscale (*Atriplex bracteosa*) and fogweed (*A. expansa*); areas 2 and 3, chinchweed (*Pectis papposa*), *Tidestromia languinosa,* and *Trianthema portulacastrum;* area 3, *Acanthochiton wrightii;* areas 4, 5, and 6, smotherweed (*Bassia hyssopifolia*). In California, Idaho, Montana, Nevada, Utah, and Wyoming, the recently introduced halogeton (*Halogeton glomeratus*), which is poisonous to livestock, is also a summer host. Siberian mustard (*Chrispora tenella*) and kochia (*Kochia scoparia*) have invaded the breeding areas of southwestern Idaho, which emphasizes the fact that the beet leafhopper and curly top problem are not static and

that the host-plant complex for both leafhopper and curly top is constantly changing.

With the maturing and drying of the summer hosts in the fall, the leafhoppers move to their winter hosts. If the summer weed hosts dry before the winter hosts germinate, the leafhoppers may be forced to feed on perennial plants and shrubs, the only available green vegetation, until the winter annuals germinate. These temporary food plants differ in the various breeding areas, as follows: Area 1, desert saltbush (*Atriplex polycarpa*), spiny saltbush (*A. spinifera* and *Lepidospartum squamatum*); area 2, creosotebush (*Larrea tridentata*), bur-sage (*Franseria dumosa*), mesquite (*Prosopis juliflora*), and spurges (*Euphorbia* spp.); area 3, creosotebush, saltbush, and snakeweed (*Gutierrezia* spp.); area 4, sagebrush (*Artemisia tridentata*), rabbitbrush (*Chrysothamnus* spp.), and snakeweed; areas 5 and 6, sagebrush and rabbitbrush. If the summer hosts dry before the winter hosts germinate, there may be a heavy mortality of the insects. If the winter hosts germinate before the summer hosts dry or are killed by frost, the mortality is greatly reduced and high leafhopper populations enter the winter.

Of the 16 important spring and summer weed hosts of the beet leafhopper listed for areas 1, 2, and 3, only filaree and Russian-thistle are introduced species; in areas 4, 5, and 6, only green tansymustard is a native. The others are introduced plants that have become established on abandoned, waste, and deteriorated range lands.

Evidently the geographical distribution of the beet leafhopper was once confined to the warmer arid regions of the southwestern United States but has spread northward as its introduced weed hosts became established. It is of interest to note that the first curly top outbreak in California occurred after Russian-thistle had become established in the State. Later investigations have shown that the outbreaks are influenced by the acreage of Russian-thistle in the San Joaquin Valley of California, Snake River Plains of Idaho, the central Columbia River area of Oregon and Washington, and to a lesser degree in Arizona, Colorado, New Mexico, Texas, and Utah.

After fields are abandoned or range is overgrazed, a succession of plants takes over. First come annual weeds, which have little forage value, followed by some annual grasses. Then, if no further disturbance occurs, this condition is followed by native perennial grasses and shrubs. The order of these changes in southern Idaho is: First, Russian-thistle; second, mustards; and third, downy chess, an introduced annual grass that is not a host of the beet leafhopper. Our observations indicate that range fires generally have their origin in areas where downy chess forms the plant cover or where it has entered deteriorated sagebrush areas to such an extent that it will carry fires. During the fire season, it is the greatest range fire hazard in the Intermountain Region; it will burn like tinder. If it is burned under favorable conditions, it may reseed itself and again form the cover, but under unfavorable conditions, such as wind erosion and trampling by livestock, mustards, principally tumblemustard, and Russian-thistle may appear. The shift from mustards and Russian-thistle to downy chess and then back to these weeds may continue in an endless cycle. On burned areas, mustards are generally first and then downy chess, but with further disturbance either Russian-thistle appears or the ground may become bare. Mixed stands of Russian-thistle and mustards are the most important combination of weed hosts for leafhopper reproduction, since the leafhoppers can overwinter and reproduce their spring and summer generations in the same area.

THROUGHOUT THEIR GEOGRAPHICAL range, many leafhoppers are destroyed each year by parasites and predators, which attack the leafhopper in all its stages and are evidently a factor in reducing the population in the breed-

ing grounds. Large numbers of eggs are destroyed by minute parasitic wasps that develop within them. The nymphs and adults of the beet leafhopper are attacked by three groups of internal parasites—the big-eyed flies (Dorilaidae), the parasitic wasps (Dryinidae), and the twisted-winged parasites (Strepsiptera). The flies and wasps deposit their eggs in or on the leafhopper, and the resulting larvae develop within or partly within its body. Upon reaching maturity, the larvae work out of the leafhopper, causing its death. The twisted-winged parasites develop differently, as the female remains within the body of the leafhopper during its entire life and gives birth to living young. These tiny larvae crawl away, attach themselves to the first leafhopper they find, and bore into its body. They seldom become of any real importance, because the chances of their finding leafhoppers in which to develop are slight. The tendency of the beet leafhopper to move about from host to host during the season apparently reduces the effect of these parasites.

Several species of predacious bugs, one being a big-eyed bug (*Geocoris pallens*), destroy large numbers of leafhoppers by sucking out their body juices. Spiders, lizards, and birds reduce the number of the insects. The grazing of livestock, principally sheep, destroys many eggs in the plants which they eat.

Reducing curly top infection in susceptible crops by controlling the leafhopper with insecticides is a difficult problem, because continuous infection of the crops occurs by reinfestation during the susceptible period.

Applications of DDT will reduce beet leafhopper numbers and have a good residual toxicity, but it will not prevent the feeding of all leafhoppers that reinfest the fields. In instances where reinfestation occurs over a 2- to 3-week period, applications of DDT and other insecticides to tomato plants have not reduced the incidence of curly top. Double-hill planting of tomatoes has given limited protection against curly top under moderate to high infestations of the leafhopper in Utah. In other instances where reinfestations do not usually occur, such as in fields of sugar-beet seed, a single application of DDT in the fall has effectively reduced curly top.

Other control methods have been developed. First, the major host plants of this insect were determined and methods for their replacement by nonhost perennial grasses were studied. The replacement of weed hosts by perennial grasses may best be accomplished by reseeding the abandoned and burned areas. If native perennial grasses are still present, protection against excessive grazing will accomplish the same purpose. Because the perennial grasses remain green until late in the season, they do not constitute a fire hazard when compared with downy chess.

The second method is the chemical control of the beet leafhopper in weed-host areas.

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